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found to be insensitive to localized currents. This indicates that the rheotropic end organs are cutaneous; of these only the tactile corpuscles were found to be of significance. This is shown by the following experiments. Under normal conditions stimulation of the lips by a glass rod produces a very violent negative reaction, and so, too, does a current of water of the sort just described. The lips of a normal fish were anaesthetized by the application of a 0.1% solution of cocaine. As a result the reaction (and assumably the sensitivity) to tactile stimulus disappeared completely, and also the reaction to the water current. Not only that, but also the parallelism between the effects of the two sorts of stimuli at any instant, both during the gradual benumbing of the lips by the reagent and during their progressive recovery from insensitivity, seemed to be complete. These facts indicate that the end organs of tactile sensitivity serve also as the essential and organs of rheotropic sensitivity. Other sensory cells, while they may in some cases be affected by currents, apparently play no necessary part in the reaction here described.

[1] Contributions from the Bermuda Biological Station for Research, No. 56.

[2] Lyon, E. P., *Amer. J. Physiol., Boston,* **12,** 1904, (149–161).

[3] Parker, G. H., *Washington, D. C., Bull. U. S. Fish. Com. for 1902,* 1903, (45–64).

[4] Parker, G. H., *Amer. Nat., Boston,* **37,** 1903, (185–204).

[5] Schulze, F. E., *Arch. mikr. Anat., Bonn,* **6,** 1870, (62–88), Taf. 4–6.

[6] Tullberg, T., *Vet.-Ak. Bih., Stockholm,* **28,** 1903, (No. 15, 25 pp.).

[7] Verworn, *Allgemeine Physiologie,* 2te Aufl., 1897, (xi + 606).

STUDIES OF THE GENUS PHYTOPHTHORA

By J. Rosenbaum

BUREAU OF PLANT INDUSTRY, WASHINGTON, D. C

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Although the actual number of species of Phytophthora is small, geographically they are very widespread, their presence having been recorded from the tropics as well as the temperate regions.

The morphological similarities between the different species, together with the great variation in the same species make the identification and separations of the species belonging to this genus exceedingly difficult. With a view to remedying this situation and determining characters of diagnostic value, nine out of the eleven described species were collected, grown in pure culture on artificial media, and studies made from a systematic and biometrical standpoint. It was not possible to procure material of *P. thalictri* and *P. colocasiae.* The following is a list of the cultures used:

P. infestans,
P. cactorum,
P. phaseoli,
P. nicotianae,
P. syringae,
P. arecae,
P. parasitica,
P. faberi,
P. jatrophae,
P. fagi, given as a synonym of P. cactorum in Saccardo.[1]

The characters to be relied on in taxonomic work must be constant under all conditions and not correlated with certain adaptations to habitat. In the work here set forth separation and relationship of species are made on the aggregate of characters, it being borne in mind that the proportionate value to be attached to each character must necessarily vary.

The most valuable characters that can be employed are doubtless those which are exhibited by the reproductive organs, and which furnish means of separating the genus into different groups. Other characters which have been found can be conveniently used in separating the various species, arranged as nearly as possible in the order of their importance, are (1) the size, and morphology of the sexual reproductive bodies, conidia, chlamydospores and other structures; (2) shape of the terminal papillum in the conidium; (3) the ratio of the length to the width of conidia; (4) variation in the mycelium, and (5) the macroscopic growth, time of appearance of spores and kind of spore forms produced on various media.

As artificial media were most generally employed, it seemed important to determine whether these media influenced the morphology and size of the various structures to any appreciable extent. Preliminary trials were made with *P. infestans* on potato foliage and artificial media, but no appreciable differences between the spore production on the potato foliage and those grown on artificial media could be detected. As far as possible, all the forms were subjected to identical conditions.

Measuring spore forms to delineate species in the various fungous groups is a well established practice. In forms less variable than those of Phytophthora a small number of such measurements might be sufficient to determine the average size. The conidia of Phytophthora, however, are so variable that a small number of measurements is apt to be misleading. For this reason four-hundred measurements were made of each form, including the length and width of conidia, the ratio of the length to the width and diameter of oospores and chlamydospores. On account of the great variability in the individual measurements, biometrical methods were used to obtain constants more readily comparable than a large mass of individual measurements. The constants obtained are the mean, median, mode, standard deviation and skewness. The measurements were made at the time of the first appearance of conidia and oospores, at which stage the cultures most nearly approach the normal. The cultures were kept at approximately 20°C.

After making a number of measurements of conidia and observing the great variation in size, it occurred to me that by continual plantings from large selected individuals cultures could finally be obtained which would produce only large conidia and vice versa. After making a large number of dilution plates and selecting single large spores for five generations, it was found that there was no material difference between the percentage of large and small conidia in the original culture and the culture resulting from the last selection.

The following summarizes the results of the above studies:[2]

1. The various forms reacted differently on different media as regards rate of growth and spore forms produced.
2. The temperature at which cultures are grown is a factor in the production of normal and comparable cultures.
3. As a minor character, the macroscopic appearance of the growth on a given medium is of some value.
4. The time of appearance of the spore forms from different strains of the same species on a given medium may vary, but eventually the same forms appear.
5. On oat agar the mycelia of the various species cannot be distinguished with any degree of certainty; on potato agar *P. syringae* can be distinguished from the remaining species by the fact that it produces characteristic tuberculate mycelia. *P. nicotianae* can likewise be distinguished to a certain extent by the more gnarled mycelia and greater abundance of globoid particles of a fatty or glycogen nature within the threads.
6. Measurement of the conidia can be employed to aid in delineating species, *provided* a sufficiently large number are measured. It is suggested that at least 200 should be measured and the different measurements grouped into classes.
7. For the purpose of obtaining a quantitive measure of the shape of the conidia the ratio of the length to the width of the conidia should be obtained and the ratios likewise grouped into classes. A comparison of the conidia of *P. parasitica* and *P. nicotianae* illustrates this point. Heretofore the differences in shape in the conidia of these two species would be expressed only qualitatively, calling the former

long and ellipsoidal, while the latter would be short and globose. Expressed quantitively, as a result of measuring the length and width of 400 individuals of each species and obtaining the ratios of the length to the width, the conidia of *P. parasitica* group themselves about a predominating ratio of 2, while *P. nicotianae* are found at 1.2. Similarly the ratios of the conidia of all the remaining species will vary from 1 + to 2 +.

8. The degree of the development of the papillum is a good character to be employed in taxonomic work.

9. In their germination of conidia by means of swarm spores, at least some of the species of Phytophthora liberate their zoospore mass into a bladder or vesicle, thus showing a greater relationship to Pythium than had been suspected.

10. Certain of the species of Phytophthora produce chlamydospores either terminally or intercalarly.

11. The measurement of the chlamydospores can be used to good advantage in delineating species. A sufficiently large number should be measured as in the case of the conidia.

12. The relation of the antheridium to the oogonium, that is whether produced at the base or on a side, can be used in separating the genus into groups, viz.: Cactorum group and Phaseoli group.

13. An additional group (Faberi group), analogous to the Fungi Imperfecti group, and embracing forms in which antheridia are absent or where their relation to the oogonium is yet unknown, is tentatively established.

14. In one of the several strains of *P. infestans* oospore-like bodies resembling those observed by other investigators were produced. Antheridia, however, were either absent, or of a very doubtful nature if present.

15. As in the case of conidia and chlamydospores, a sufficiently large number of measurements of the oospores should be made if the measurements are to be used in identifying a species.

16. On account of the variability in the size of the spore forms belonging to this genus, a more ready comparison can be made by the use of biometrical constants than by a mass of individual measurements. Such biometrical constants were calculated and arranged into tables. By the use of these constants the identity and relationship of the species are further confirmed.

17. In closely related genera, such as Pythium, Pythiacystis, Peronospora, Plasmopora, and Sclerospora, the identification and separation of species are made with difficulty. Many of the diagnostic

characters enumerated in this paper can be employed to good advantage in the identification of species belonging to these genera.

[1] Saccardo, P. A., *Phytophthora cactorum* (C. et L.), *Schroet. Syll. fung.*, 7, 1888, (238).
[2] The complete paper is published in *J. Agric. Res.*, 8, 1917, No. 7.

A POSSIBLE FUNCTION OF THE IONS IN THE ELECTRIC CONDUCTIVITY OF METALS

By Edwin H. Hall

JEFFERSON PHYSICAL LABORATORY, HARVARD UNIVERSITY

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The following paper is a development, in certain particulars, of a suggestion concerning electric conduction in metals which I made in *Il Nuovo Cimento* for January-February, 1915. It rejects the free electrons within the metal as the vehicle of the electric current and puts in their place for this function the metal ions, necessarily equally numerous with the free electrons. Briefly stated, the idea of conduction which I have had in mind is the following:

At very low temperatures the atoms of a metal are packed so closely that electrons pass readily from one to another in a continuous procession through the metal, if there is an applied electromotive force to maintain progression in one direction. Free electrons and metal ions, if indeed ionization exists at the lowest temperatures, need not be called into action here.

With rising temperature the heat vibrations separate the atoms so that they are not always in conductive contact, and not very many degrees above the absolute zero they are, on the average, so far apart that conductive contact between them is exceptional.

In this state of things an electron will not in fact pass from one metal particle to another, even when they are in the closest contact of a collision, unless one of these particles is an atom and the other an ion. Figures 1 and 2 illustrate the fundamental difference, from the point of view of conduction, between an atom-atom collision and an atom-ion collision. In figure 1 the electric force tending to carry the extra electron of the left-hand particle back to the positively charged right-hand particle, just before the particles separate, must be enormously larger[1] than the greatest conteracting force we can apply from without. But in figure 2 the extra electron may belong as much to one particle as to the other, when once the particles meet, and a comparatively small general gradient of potential in the metal, due to an electromotive force